Oscillatory and Fractal Biomarkers of Human Memory

Joseph H Rudoler, Nora A Herweg, Michael J Kahana

Background

Studies analyzing the relationship between theta-band and other low frequency brain oscillations have yielded mixed results.

Herweg, Solomon, and Kahana (2020) proposed in a review of theta oscillations that:
- Changes to the 1/f background spectrum of neural activity might obscure oscillations
- Positive effects might be due to theta synchrony rather than true power changes
- Theta might be specific to associative memory and not subsequent memory effects

We aim to separate narrowband, oscillatory effects from the background spectrum and better understand the oscillatory correlates of human memory.

Methods

The Irregular Resampling Auto-Spectral Analysis (IRASA) separates broadband changes in the fractal background spectrum from narrowband oscillations. IRASA treats an EEG trace as a linear combination of an oscillatory component and a "fractal" pink noise component which is assumed to follow a power law distribution.

Studies analyzing the relationship between theta-band and other low frequency brain oscillations have yielded mixed results.

Herweg, Solomon, and Kahana (2020) proposed in a review of theta oscillations that:
- Changes to the 1/f background spectrum of neural activity might obscure oscillations
- Positive effects might be due to theta synchrony rather than true power changes
- Theta might be specific to associative memory and not subsequent memory effects

We aim to separate narrowband, oscillatory effects from the background spectrum and better understand the oscillatory correlates of human memory.

Bipolar referencing of iEEG is a spatial high-pass filter, so we repeated our retrieval analysis with a more global scheme that would theoretically capture more theta synchrony.

A clear trend in oscillatory power emerges at both encoding and retrieval: successful memory is accompanied by an increase in Theta, a decrease in Alpha, and an increase in Gamma (TAG).

Theta and alpha are highly correlated at encoding (R = -0.45, p = 1.97 x 10^-15)

Electrodes which exhibited more spectral tilt - a flattening of the fractal spectrum - showed less oscillatory theta for successful memory.

Conclusions

1) IRASA is an effective tool for studying narrowband oscillatory correlates of cognitive function without the confound of broadband changes in brain activity
2) Pure oscillatory power shows a theta increase, alpha decrease, and gamma increase (TAG) for successful memory at both encoding and retrieval
3) The positive theta SME at encoding was simply masked by a broadband decrease in fractal power, as hypothesized by Herweg, Solomon, and Kahana
4) Choice of reference scheme as a spatial filter has no effect on TAG
5) Oscillatory theta does not have a unique relationship with associative memory